DEVELOPMENT OF NIGHT VIEW SYSTEM

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ABSTRACT

We have developed a Night View system to assist a driver's vision during night driving. This system can capture an image beyond the range of low beam headlights with near-infrared camera and display a monochrome virtual image onto the windshield in front of the driver. To avoid startling the driver of an oncoming vehicle, this system projects a near-infrared ray, which is hardly visible to the human eye.

Because a virtual image is displayed on to the windshield, we have optimized the position, size and brightness of the head-up display (HUD) to enhance a driver's view during night driving. A switch is provided to turn the system on and off and to control the HUD's brightness. This system can be effective without impairing typical night driving.

1. INTRODUCTION

In Japan, traffic accidents occurring at nighttime account for 53% of all traffic accidents (number of fatal accidents in 2001, National Police Agency). The driver can make decisions during the daytime driving according to information gained from a wide angle of views. When using high-beam headlights at night, illuminating more than 100 meters in front of a vehicle, the driver can accurately make judgments to avoid obstacles seen within the area illuminated by the headlights and then control the vehicle accordingly. When using low-beam headlights, the driver controls the vehicle assessing the conditions ahead from limited information gained within about a 40-meter illumination range of the headlights, by the light from streetlights, etc. Under these conditions the driver may sometimes fail to avoid obstacles depending on vehicle speed.

It is very important to develop measures against this hazard when there are not many lanes present as well as when there are many oncoming vehicles since a vehicle in such an area is driven principally with the headlights on low beam. The driver will be better able to predict hazardous conditions earlier and have more time to take suitable actions if it is possible to provide information on road conditions (the presence of objects, road features, road gradient, etc.) ahead of the range of the low beam headlights.

We selected a near-infrared camera to obtain information on the conditions ahead of the low beam illumination range while avoiding disturbance to drivers of oncoming vehicles.

2. SYSTEM CONSTRUCTION

Figure 1 shows an outline of the newly developed system. Figure 2 shows the system construction. The system consists of two near-infrared floodlights, a near-infrared camera capable of visualizing near-infrared beams, a head-up display (HUD) providing the driver with images, and a control unit and switch for controlling each of the components.

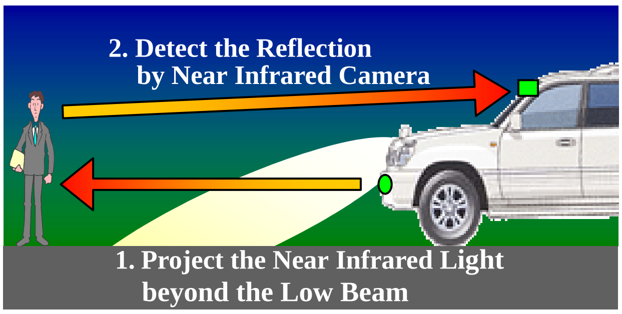


Figure 1 . System Outline

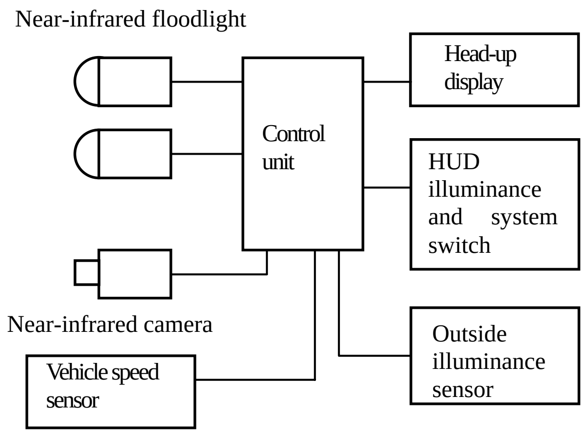


Figure 2. System Block Diagram

2.1 Near-Infrared Floodlight

The near-infrared floodlights project near-infrared beams at a distance comparable to that possible by high-beam headlights, when turning on low-beam headlights while driving. A filter is added to a halogen lamp to cut out rays in the visible light spectrum so that only near-infrared light is cast forward.
This filter realizes light distribution equivalent to that of high-beam headlights and ensures the projection of only near-infrared beams without startling drivers in oncoming vehicles. The energy of the near-infrared light is equal to that of high beam headlights. The filter is designed so that only infrared light is distributed and rays do not leak to prevent the floodlight from being mistaken as a red light.

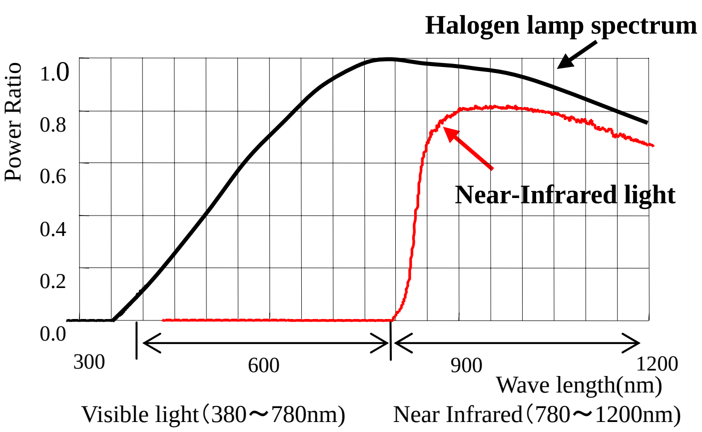


Figure 3. Spectroscopy of Near Infrared Floodlight

2.2 Near-Infrared Camera

The near-infrared camera has been newly designed, incorporating a one-third-inch general-purpose charge-coupled device (CCD). We have made improvements to the camera by cutting out rays of the visible light spectrum and controlling reflection inside the camera to achieve a larger dynamic range.

(1) Mounting of a filter with the same visible light cutting characteristics as the near-infrared floodlight.
(2) Anti-reflection coating on lens surfaces for avoidance of ghost images
(3) CCD front mask for avoidance of ghost images
(4) Construction for avoidance of indirect light caused by reflection inside the lens barrel

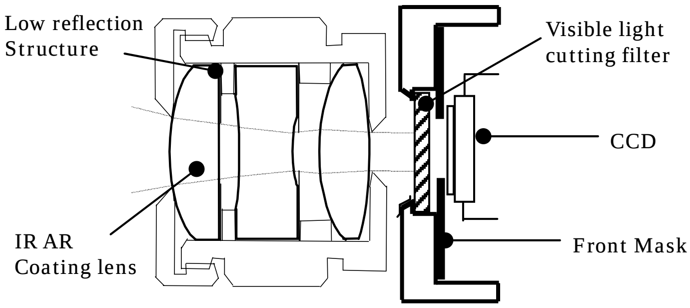


Figure 4. Cross-sectional View of the Near-Infrared Camera

2.3 Head-Up Display (HUD)

Images taken by the near-infrared camera are presented to the driver by means of the HUD. The driver sees images as if they are displayed at the front, outside the vehicle, and at the bottom of the windshield, as shown in Figure 5. The brightness of the image is adjusted with a switch. A shutter is provided for the HUD unit to improve its appearance during daytime driving and to protect it from sunlight.

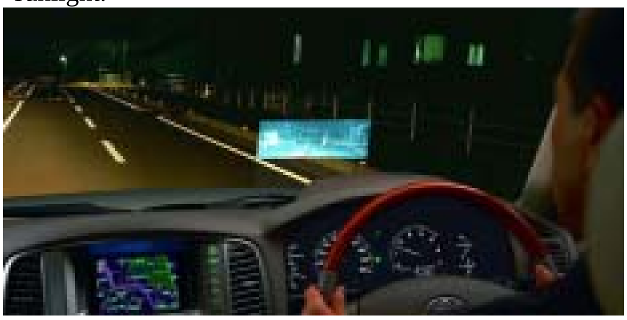


Figure 5. HUD is projected in front of the Driver.

2.4 Control Circuits

The control circuits control the near-infrared floodlight, near-infrared camera, HUD, and other components in response to switch operation, vehicle speed, and illuminance data inputs. The control circuit logic is designed to operate only at nighttime for the protection of the camera and HUD.

3. ENHANCING THE DRIVER'S VISION WITH THE HUD IN USE

3.1 HUD Display Position

The HUD permits the driver to see near-infrared images without moving the direction of his/her gaze very much from the typical vision used during night driving. However, the driver' s direct vision could be disturbed if the HUD is installed inappropriately or if the displayed images are not appropriate. In Japan, the Ministry of Land, Infrastructure and Transport has established technical guidelines on devices for vehicles that provide information on conditions ahead during night driving. These guidelines are designed to help ensure that the device does not disturb the driver. Representative terms in the guidelines are shown below.

- Operating conditions: The device operates only when the low-beam headlights, high-beam headlights, or front fog lamps are turned on.
- Control: The control unit of the device must be operated with ease by the driver in the driver' s seat and be provided with a switch to allow the driver to start or stop the device at will.
- Image display position: The image, if displayed within the windshield area, must be below the plane passing the V2 point (defined by seating reference point and seat-back angle of the driver seat) and making a downward angle of one degree with respect to the horizontal plane. The image must not be displayed within the range defined by connecting the eye point and rear view mirrors.
- Image illuminance: It must be possible to adjust the illuminance to 30 cd/m^2 or less to avoid startling the drivers. The maximum brightness must be 100 cd/m^2 or less to help ensure that the driver' s vision is clear. Red color must not be used.

The newly developed system follows these guidelines, with the HUD presenting images taken by the near-infrared camera at a position approximately 800 mm ahead of the driver's eye position with a size of 130 mm in width and 42 mm in height.

3.2 Anti-halation Measures against Headlights of Oncoming Vehicles

The newly developed system uses a CCD camera sensitive in the near-infrared range and displays an image of objects ahead of the vehicle at nighttime. The operating principle of the CCD produces halation (spreading of light beyond its proper boundaries) of external light such as headlights of oncoming vehicles due to dynamic range restrictions. Halation is likely to occur in images if an object is very bright when directly seen by the human eye at nighttime. The major problem with a near-infrared system is this image degradation.

Before

After

Figure 6: Effect of Anti-halation Improvement

In order to minimize image degradation caused by halation, we tuned the *gamma* characteristics of the near-infrared camera and the HUD, in addition to the above-mentioned improvements to the camera itself. The equipment we tuned so that high contrast is produced between the surroundings and obstacles.

Figure 6 shows is a system capable of 1) reducing the brightness of intense light such as headlights of oncoming vehicles, and 2) displaying human figures near oncoming vehicles with higher contrast.

3.3 Control-Related Features

The newly developed system includes a rotary switch for brightness control to prevent the system from interfering with the driver's vision. When driving from the suburbs to a city, for example, HUD images may become unnecessary due to bright illumination in the urban area. A pushbutton switch is, therefore, essential for turning images on and off at will. The system is turned off whenever the engine is shut off. The newly developed system is a support system for the driver, therefore, it is designed to confirm the driver's intent (to switch on) when it is started. The system operates only when the surrounding illuminance is low to avoid unnecessarily turning on the HUD during the day.
The driver should have little trouble driving with the vision available using low-beam headlights when the vehicle is stationary. On other hand, because the infrared light is invisible, there is a opportunity for the pedestrian to gaze the infrared flood light when the vehicle is stationary. Therefore, we adopted particular control logic to turn off the Near Infrared floodlight when the vehicle is not moving.

4. RECOGNITION PERFORMANCE

4.1 Evaluation of Recognition Performance on Proving Ground

We compared visions gained by low- beam and high-beam headlights with images presented by the night view system, with persons dressed in black and in white standing at the center of a lane 100 meters ahead of the vehicle. Figure. 7 shows that it is possible to recognize human figures using this system although they cannot be seen using low-beam headlights. Even though the person dressed in black is difficult to see with high-beam headlights, this system still displays a clear image of it.

Driver's View with Low-Beam

Driver's View with High-Beam

Near Infrared Image

FIGURE 7. Comparison of Recognizing Pedestrian at 100m ahead of the Vehicle. Left Side Dressed in Black, while Right Side Dressed in White.

Table 1 shows sensory recognition results obtained at various distances without halation. The circle means target can be seen. The triangle means target can be seen partially. The cross means target cannot be seen. The system allows the driver to find human figures 150 meters ahead with low-beam headlights. Information on the surroundings can be provided from even 250 meters ahead if using high-beam headlights together with the night view system.

	Low Beam		Hi Beam		Night View (Low Beam)		Night View (Hi Beam)	
	W	B	W	B	W	B	W	B
50m	O	X	O	△	O	O	O	O
100m	X	X	O	X	O	O	O	O
150m	X	X	O	X	O	O	O	O
200m	X	X	△	X	O	O	O	O
250m	X	X	X	X	△	△	O	O

W: White-clothed pedestrian B: Black-clothed pedestrian

Table1: Evaluation Table about Recognizing Pedestrian

We measured the human figure recognition rate in various conditions. The results of the sensory evaluation indicate that it is possible to recognize human figures if their illuminance is 55% or higher. The above-mentioned improvements made to the camera and HUD have improved illuminace of human figures higher even with oncoming vehicles. According to the evaluation test, recognition performance for human figures approximately 130 meters ahead with oncoming vehicles and approximately 170 meters ahead without oncoming vehicles, while the vision available with low-beam headlights is approximately 40 meters ahead (Figure 8).

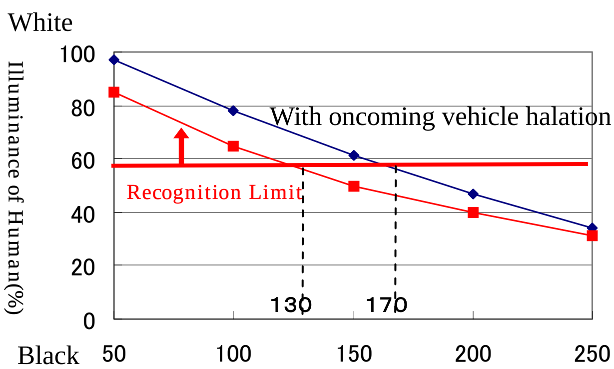


Figure 8. The illuminance of human figure vs. distance.

4.2 Performance on the Road

We tested the performance of the newly developed system on an actual road. Pedestrians crossing the road are clearly seen in the image with the night view system. Object positions are correlated with ease between the displayed image and direct vision since the surroundings are also captured in the image.

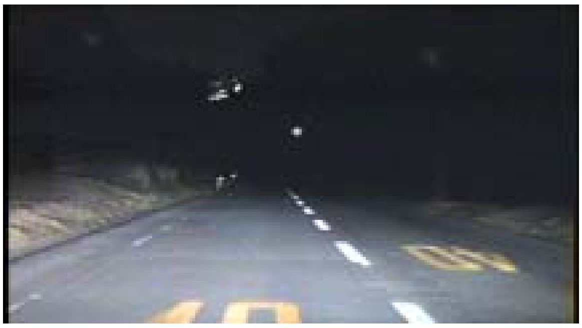
Drive's View with Low-Beam

Near-Infrared Image

Figure 9. Effect to Recognize the Pedestrian across the Road

It is also possible to display the features of the road ahead as part of the surroundings. The driver develops a feeling of safety since the system reveals whether the road curves or not.

In the suburbs, animals often cross the roads. Although the newly developed system is incapable of highlighting animals, it does allow the driver to recognize objects that are difficult to see using direct vision.



Driver's View with Low-Beam

Near Infrared Image

Figure 10. Effect to Recognize the Road Features

4.3 HUD Glance Time

Even though the night view system shows lots of information on HUD, we measured the HUD glance time using eye mark recorder. Figure 11 shows the HUD glance time during driving. The length of each glance time is around 1 second, which is almost the same as the rear view mirror and the navigation system's glance time. From the viewpoint of glance time, we think the night view system does not cause excessive glance times.

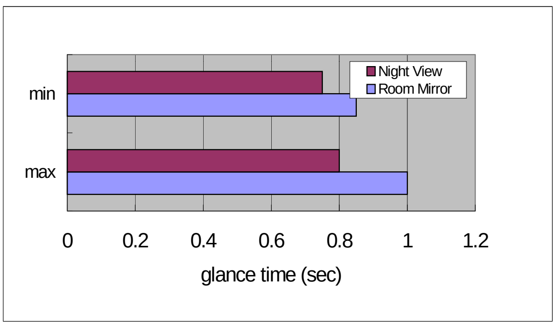


Figure 11. The Glance Time in the Real Driving, HUD vs. Rear View Mirror

5. CONCLUSION

Near-infrared beams are emitted by various light sources, including the headlights of oncoming vehicles. Consequently, a problem of existing systems with a limited dynamic range is the startling halation to the driver. This newly developed system incorporates improvements in the HUD's display method and anti-halation measures to supplement the limited dynamic range of the camera, making it possible to reduce headlight brightness of oncoming vehicles and, at the same time, to display human figures in dark surroundings. The newly developed system has proved that night view support systems using near-infrared beams are feasible for actual driving.

Further possibilities exist for providing better images by improving the development of a photoreceptor with a wide dynamic range and improving the image processing software used. We anticipate that as more vehicles install the newly developed system, traffic accidents caused by driver's reduced vision during night driving will decrease.

REFERENCES

1. Nancy S. Martinelli, Scott A. Boulanger, Cadillac Deville Thermal Imaging Night Vision System, SAE Technical Paper Series 2000-01-0323, World Congress Detroit, Michigan,(2000)
2. Lukas Kupper, Josef Schug, Active Night Vision Systems, SAE Technical Paper Series 2002-01-0013, World Congress Detroit, Michigan,(2002)
3. Peter M. Knoll, , A NIR Based System for Night Vision Improvement, Convergence 2002-21-0029